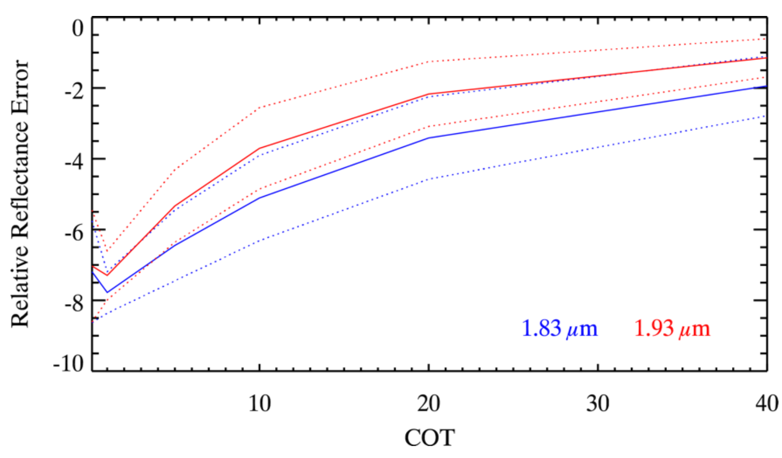
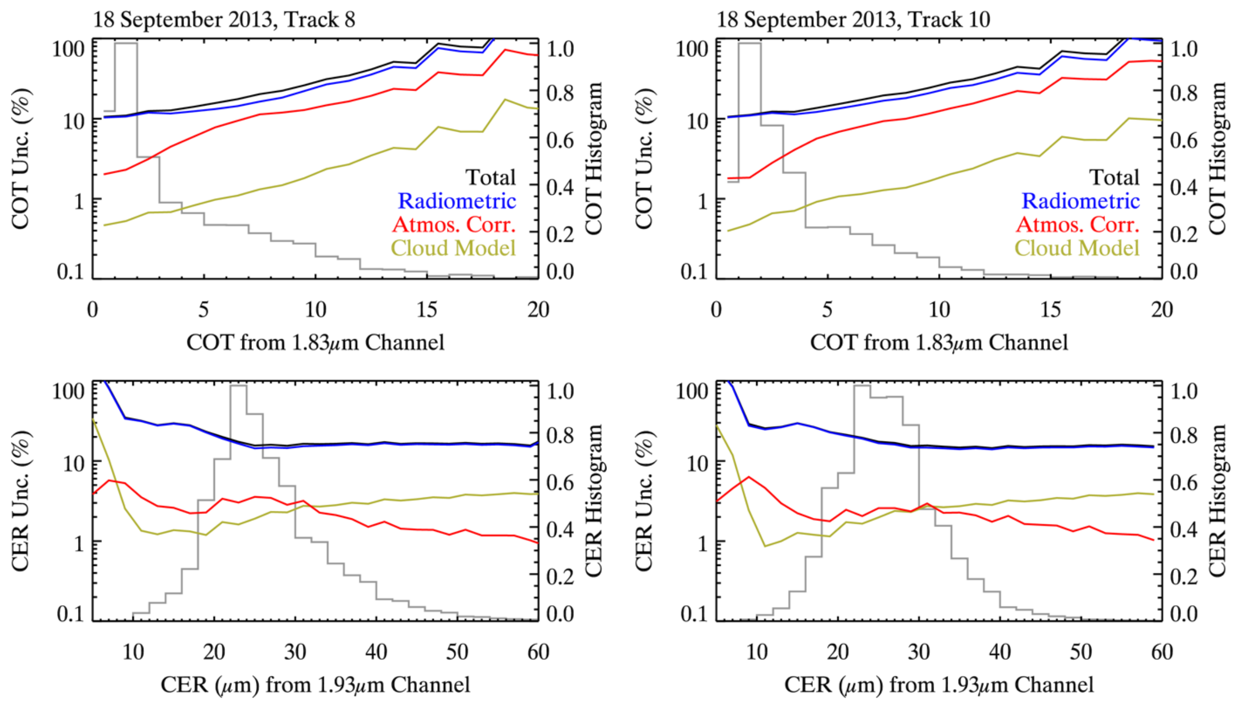
The authors would like to offer a response to comments received via personal communication regarding the sensitivity of the present approach to in-cloud water vapor absorption. An important observation has been made that the channels within the 1.88μm water vapor absorption band used here are sensitive to water vapor absorption within the cloud layer itself, which, as has been correctly pointed out, is not explicitly accounted for in the cloud retrieval look-up tables nor in the above-cloud atmospheric correction. As was suggested to us, we performed a sensitivity analysis using high spectral resolution (0.1nm spacing) forward radiative transfer (RT) simulations that couple line-by-line column transmittances from LBLRTM with DISORT such that the eMAS 1.83μm and 1.93μm spectral response functions can be used to compute band-averaged TOA reflectances. The RT calculations were performed for a 1km thick ice cloud located at 12km altitude (an altitude similar to the case studies in the paper), varying COT (0.1 to 40), CER (5 to 55μm), cosine of the sensor zenith angle μ (0.45 to 1.0), cosine of the solar zenith angle μ_0 (0.15 to 1.0), and relative azimuth angle (0 to 180°). Two RT simulations were performed, one with water vapor above- and in-cloud, and one with water vapor above-cloud only; in both cases the surface was assumed to be non-reflecting. We found the TOA reflectance bias between the two RT runs to be a function primarily of cloud optical thickness (COT) as expected due to increasing in-cloud path lengths with COT. While the absolute reflectance difference increases with COT, the relative difference decreases, with a maximum relative error of roughly 7-8% at COT=1; the mean relative bias is at roughly 1-2% at COT=40. This is shown in the figure below, in which mean (solid lines) and ±1σ (dotted lines) reflectance errors are plotted as a function of COT for 1.83μm (blue) and 1.93μm (red); relative reflectance errors are defined here as the difference (R[in+above]-R[above])/R[above], which is comparable to the atmospheric correction bias such that negative values imply an under-correction for atmospheric absorption (i.e., darker atmospherically-corrected reflectance) and thus smaller retrieved COT and larger retrieved CER. However, note that these biases are nevertheless smaller than the 10% radiometric uncertainty assumed for the 1.83μm and 1.93μm channels (see p. 12, line 279).



From the below plots showing COT and CER retrieval uncertainty from individual uncertainty components (data are from the two SEAC^{4}RS case studies shown in the manuscript), it is evident that a 10% error (i.e., the blue line denoting radiometric uncertainty) corresponds to COT uncertainty of roughly 10-20% over much of the observed COT distribution (though much larger at larger COT), and CER uncertainty of roughly 20-30%. While these uncertainties are large, it should be reemphasized that 10% uncertainty is larger than the TOA reflectance sensitivity to in-cloud water vapor absorption (as stated above, roughly 7-8% at its peak); in fact, at COT=1 the

10% radiometric uncertainty yields a COT retrieval uncertainty of about the same magnitude (CER retrieval uncertainty is approximately double). Thus explicitly ignoring in-cloud water vapor absorption in the present retrievals should be expected to result in smaller retrieval errors than those that result from the radiometric uncertainty (and in fact considerably smaller errors for much of the COT solution space). However, unlike radiometric uncertainty, we acknowledge that the in-cloud water vapor absorption error source is expected to involve a bias (i.e., smaller COT, larger CER) over much of the COT space in addition to a random component.



That said, in-cloud absorption is implicitly accounted for at least partially by the above-cloud atmospheric correction process, assuming the radiative cloud top height retrieved from the thermal IR channels is located below the physical cloud top observed by the lidar. Thus the path length from TOA to the radiative cloud top is expected to include part of the cloud layer itself. This is typically the case when using the heritage 11µm IR-window and 13µm CO_2-slicing cloud top retrieval techniques (see, e.g., Holz et al., 2008), whose results will be similar to the OE-IR cloud top retrievals shown in Figs. 5 and 7 that use identical spectral information. We note, however, that for the present investigation we use the cloud top retrievals from the NOAA AWG PATMOS-x algorithm, consistent with the archived eMAS cloud products that were produced for the SEAC^{4}RS field campaign at the time of this writing. These retrievals are, at least for the case studies shown here, near the cloud top observed by CPL. Nevertheless, to the extent that the AWG PATMOS-x retrievals provide a radiative cloud height that is below the physical cloud top, their use can at least partially offset the impacts of explicitly ignoring the in-cloud water vapor absorption in the forward-calculated LUTs and atmospheric correction. Finally, we note that in practice it is impractical to estimate the exact in-cloud water vapor absorption (or the errors resulting from its neglect) at pixel-level due in part to the lack of a computationally efficient on-line RT algorithm that necessitates the use of pre-computed LUTs, as well as the general ignorance of the retrieval algorithm to pixel-level radiative cloud top retrieval biases. We have added to the manuscript a brief summary of the above discussion of the in-cloud water vapor absorption sensitivity (p. 10-11, lines 235-259), as well as other details regarding the above-cloud atmospheric correction process (p. 10, lines 218-230).

References

Holz, R. E., Ackerman, S. A., Nagle, F. W., Frey, R., Dutcher, S., Kuehn, R. E., Vaughan, M. A., and Baum, B.: Global Moderate Resolution Imaging Spectroradiometer (MODIS) cloud detection and height evaluation using CALIOP, J. Geophys. Res., 113, doi:10.1029/2008JD009837, 2008.